Small Business Innovation Research/Small Business Tech Transfer

Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics, Phase II

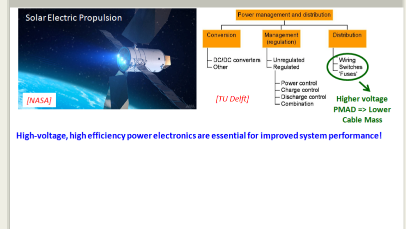
Completed Technology Project (2017 - 2021)

Project Introduction

Future NASA science and exploration missions require significant performance improvements over the state-of-the-art in Power Management and Distribution (PMAD) systems. Space qualified, high voltage power electronics can lead to higher efficiency and reduced mass at the spacecraft system architecture level, and serve as an enabling technology for operational concepts such as solar electric propulsion. Silicon carbide (SiC) is a robust technology with superior electronic properties for power applications. SiC devices offer higher temperature operation, lower on-resistance, higher breakdown voltages, and higher power conversion efficiency than silicon devices. However, high vulnerability to heavy-ion induced degradation and catastrophic failure has precluded this technology from space PMAD applications. Importantly, physical mechanisms for this vulnerability are not well understood, resulting in the inability to develop radiation hardened SiC devices. CFDRC, in collaboration with Vanderbilt University and Wolfspeed, is applying a coupled experimental and physics-based modeling approach to address this challenge. In Phase I, we performed electrical and heavy ion tests on 1200V Wolfspeed SiC JBS diodes to generate response data, and performed TCAD simulations to investigate diode sensitivity to design parameters and analyze electro-thermal mechanisms behind measured response. In Phase II, we will develop further insight into physical mechanisms in the diodes via development and application of advanced physics models. We will parametrically analyze design features to identify promising hardness solutions, which will then be fabricated and experimentally characterized. We will also perform heavy-ion testing of 1200V SiC MOSFETs and apply simulations for insights into governing mechanisms (to be further developed in follow on work). Direct participation by Wolfspeed in Phase II and beyond will ensure space-qualified, SiC power devices for NASA applications.

Anticipated Benefits

Space qualified, high voltage/high temperature power electronics is directly aligned, per the NASA Space Power and Energy Storage Roadmap - Technology Area (TA) 03, with science and exploration missions such as: missions using electric propulsion, robotic missions, lunar exploration missions to Near Earth Orbit, robotic surface missions to Venus and Europa, polar Mars missions and Moon missions, and others. A higher operating voltage can yield a lower distribution system weight for the same power level and is highly desirable across many areas of PMAD. SiC devices offer higher breakdown voltage, lower switching losses, and increased temperature tolerance, all crucial features for NASA space power applications. The radiation tolerant SiC designs from this project will add to the NASA components library. The TA 03 roadmap identifies the development of analytical models and predictive tools to model and characterize power and energy storage systems as a Cross-Cutting Technology which will provide capability to all NASA missions that require power electronics. Specifically highlighted is the need for



Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics, Phase II Briefing Chart Image

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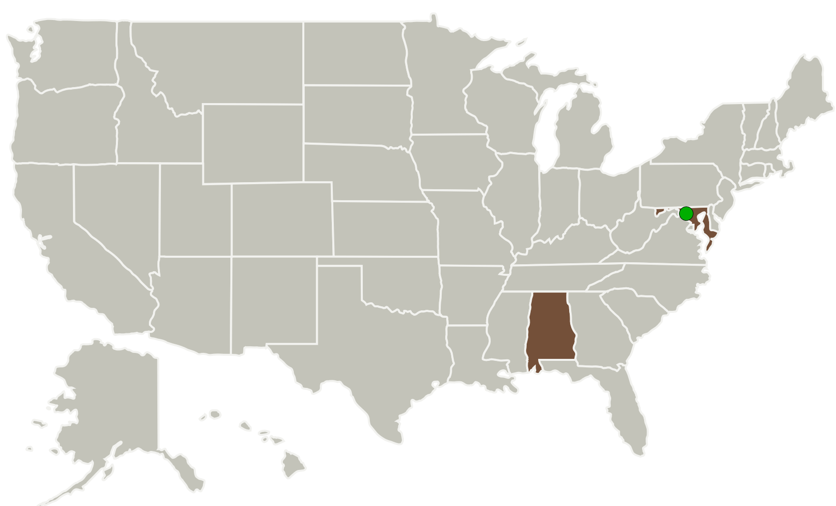
physics-based models of power-related components. The modeling and analysis tools developed here directly address this need, and will help NASA better evaluate device performance under radiation and high temperature at an early stage, and design space qualified power electronics with better understanding and control of design margins, thereby reducing development time and cost.Space qualified SiC power electronics will find application in power systems in all space-based platforms, including DoD space systems (communication, surveillance, missile defense), and commercial satellites. High voltage SiC power devices, through applications in inverters, high-voltage converters, motor drives, and switch mode power supplies, also offer significant performance benefits to power systems in other market sectors. These include national defense systems such as unmanned underwater vehicles (AUVs) and soldier portable power systems. Applications in the terrestrial energy sector include PMAD systems in all-electric and hybrid cars, grid-scale energy storage systems, smart grid, green energy systems (wind/solar systems), solid-state lighting, and remote, off-grid power systems (crewed vehicles and habitats). Other commercial applications of SiC include high temperature power and control systems for extreme environments such as geothermal drill sites and sensor systems in engines of aircraft and hybrid vehicles. For all the applications listed above, physics-based predictive and accurate modeling and design tools reduce the amount of required radiation/temperature testing, thus decreasing their cost, and time to market or field application.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

CFD Research Corporation

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

Carlos Torrez

Project Managers:

Joseph Famiglietti
Jean-marie Lauenstein

Principal Investigator:

Ashok Raman

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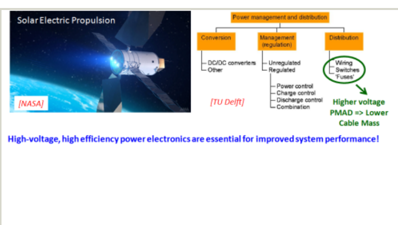
Organizations Performing Work	Role	Type	Location
CFD Research Corporation	Lead Organization	Industry	Huntsville, Alabama
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations	
Alabama	Maryland

Images



Briefing Chart Image
Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics, Phase II Briefing Chart Image *(https://techport.nasa.gov/image/131530)*

Technology Maturity (TRL)

Start: **4**
Current: **5**
Estimated End: **5**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Target Destinations

The Sun, Earth, The Moon, Mars, Others Inside the Solar System, Outside the Solar System